Antiferromagnetism and magnetoleasticity of UNiAl

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Abstract

We report on a thermal-expansion (TE) and magnetostriction (MS) study of the antiferromagnet UNiAl at temperatures 2 - 90 K and in magnetic fields up to 16.5 T applied along the *c*-axis. The TE along the c-axis (in 0 T) exhibits a broad valley centered around 35 K. This anomaly is nearly removed in 16.5 T. For $T \leq 7$ K a sharp metamagnetic transition (MT) observed in UNiAl at 11.4 T and it is accompanied by abrupt MS effects of $+1.3 \times 10^{-4}$ and -1.8×10^{-4} along the *a*- and *c*-axis, respectively. In fields above the MT a negligible additional negative MS is induced along *c* whereas the *a*-axis and consequently the volume expand considerably, which indicates a field-induced enhancement of the U magnetic moment. $T > 7$ K, the MT becomes gradually smeared out but a non-negligible MS is observed even for $T > T_N$. In the light of these results the TE anomaly measured in zero field may be attributed to AF that survive at temperatures far above T_N.

Key words: UNiAl; single crystal; thermal expansion; magnetostriction;

1. Introduction

UNiAl is an itinerant $5f$-electron antiferromagnet ($T_N = 19.3$ K) characterized by strong uniaxial anisotropy, reduced U moments and a considerably enhanced γ -value. For $T \leq 7$ K and in a magnetic field parallel to the *c*-axis of hexagonal structure UNiAl undergoes a sharp metamagnetic transition (MT) at $B_c \approx 11.4$ T, which is accompanied by anomalies of electronic properties [1]. For $T > 7$ K the MT becomes gradually smeared out with increasing temperature. The thermal expansion (TE) of UNiAl is highly anisotropic. The *a*-axis is monotonously expanding with increasing temperature. Along the *c*-axis, the lattice first collapses with increasing temperature up to 35 K. Above 35 K a continuous stretching is observed [2]. This anomaly motivated our dilatometric study of UNiAl in magnetic fields, which is reported here.

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2. Experimental details

The studied sample with dimensions $3.8 \times 2.1 \times 3.7$ mm (in *a*, *b* and *c* directions, respectively) is a part of a single crystal reported in [3]. The dilatometric measurements were performed on along the *a*- and *c*-axis using a capacitance micro-dilatometer [4]. The magnetic field up to 16.5 T was applied along the *c*-axis.

3. Results and Discussion

The TE behavior along *c*-axis is shown in Fig. 1. The zero-field data are in agreement with [2]. The TE at temperatures below 40 K is very sensitive to applied magnetic field along the *c*-axis. And the minimum on the $(\Delta L/L)_c$ vs. T dependence observed in 0 T is nearly removed in a field of 16.5 T leaving a weak broad shoulder above 20 K.

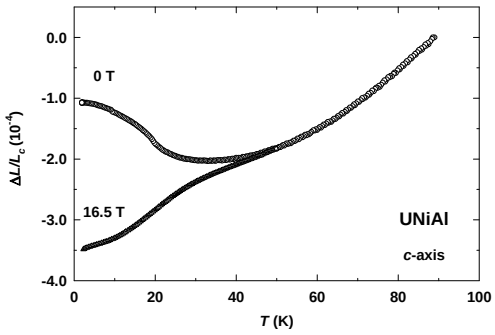

Fig. 1. Temperature dependence of the length of a UNiAl single crystal along the c-axis in 0 and 16.5 T applied along the c-axis.

Fig. 2 displays the MS data measured along the a and c-axis, respectively. For simplicity only results obtained at the lowest temperature and somewhat above $T_{\rm N}$ are displayed. At the lowest temperature the MT is observed at 11.4 T where the a-axis (c-axis) MS curve exhibits a sharp increase by 1.3×10^{-4} (decrease by 1.8×10^{-4}). The two MS effects, which are of opposite sign, almost compensate and yield only a very small volume expansion of 0.8×10^{-4}. The MT between the low-field AF state and the high-field ferromagnetic arrangement of U moments [5,6] is connected with a suppression of AF coupling. The volume expansion may be connected with an enhancement of the itinerant U magnetic moment. Non-negligible MS effects are observed along the both crystallographic directions also in magnetic fields below MT, however the two effects are of opposite sign and compensate completely and the lattice volume remains constant up to 11 T. In both cases the linear MS is proportional to the square of the magnetization. One can also see in Fig. 2 that in fields above the MT a negligible additional negative MS is induced along the c-axis whereas the a-axis expands considerably. The resulting volume expansion probably indicates a field-induced enhancement of the U magnetic moments. Neutron-diffraction measurements in high magnetic fields are planned to prove this hypothesis. With increasing temperature above 7 K, the MT becomes gradually smeared out but a non-negligible MS is observed for both crystallographic directions even for at temperatures much higher than $T_{\rm N}$.

The evolution of TE and MS with temperature and magnetic field in UNiAl resembles to a certain extent the temperature and field dependence of electrical resistivity and magnetoresistance (MR) [7,8]. A negative MR is observed at the MT when the AF arrangement of U atoms is destroyed and the application of magnetic field modifies the anomalous resistivity of UNiAl towards behavior of a normal metal. Also our preliminary measurements of specific heat indicate considerable isothermal entropy changes induced by sufficiently high magnetic fields.

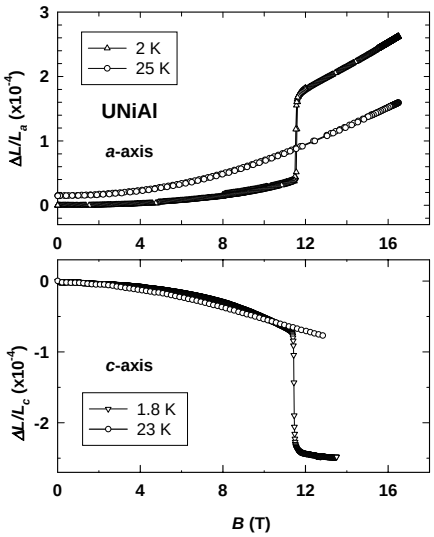

Fig. 2. The a- and c-axis MS of UNiAl at two representative temperatures as a function of the magnetic field applied along the c-axis.

We tentatively attribute both the anomalous TE and resistivity behavior of UNiAl above $T_{\rm N}$ to AF correlations surviving in this compound at least up to 2 $T_{\rm N}$. This conclusion is corroborated by neutron scattering results [8]. Sufficiently high magnetic fields applied along the c-axis suppress the AF correlations and modify the TE and electrical resistivity towards the behavior expected for a normal metal.

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